Chapter

RFA and Its Use in Implant Dentistry

Charles D. Schlesinger

Abstract

For over two decades the use of resonance frequency analysis or RFA has been used as a tool to determine the stiffness of implants in bone. Through the years the technology has become better, smaller and more accurate. Today, the use of RFA has been proven to be far superior to other clinical techniques to determine implant stability and is used not only to increase the level of success for implantologists around the world, but also to further the study of implant technology development.

Keywords: Implants, Stability, RFA, Treatment decisions

1. Introduction

Over the last two and half decades, the use of RFA instrumentation has gone from being an experimental gadget to an everyday and necessary instrument in determining implant stability and the overall health of the peri-implant/implant interface. This chapter will delve into the technology and its use in the modern day practice as well as ongoing research.

Clinicians generally agree that it is important to verify the status of implant–bone interface before attachment of prosthetic abutment, after completion and insertion of the definitive prosthesis [1].

Modern implantology has progressed to a point where our treatments are predictable, our outcomes better and our healing times shorter. Much of this is a direct result of better micro and macro implant characteristics. The modern implant with its osteo-promotive surface, better thread geometry and internal prosthetic connection allows clinicians to treat patients that historically would have had a guarded-prognoses at best.

Resonance Frequency Analysis, other was known as RFA is a technology that has become the standard by which an implantologist can measure the degree of integration not only prior to restoring an implant, but it can also be used to determine the progression of integration during the healing phase.

Prior to the development of these instruments and use of RFA for the determination of implant stability, the measurement of implant stability was rudimentary at best. It relied on blunt tapping, reverse torque, Seating torque, a Periotest device or time. Each of these methods have their limitations and ultimately are not reliable predictors of implant stability.

Before we delve into the specifics or RFA, lets first look at the other methods of determining implant stability.

2. Blunt tapping

The use of a blunt instrument such as a mirror handle has been used to determine, in a very crude fashion, the stability of an implant. The metallic mirror handle is tapped against an implant, a cover screw, a healing abutment or a definitive abutment. The clinician then listens to the sound that occurs and relates that to the stability of the implant in the peri-implant bone. As you can imagine, there is a lot of room for interpretation and experience is the key to predictability in this method.

3. Torque at implant placement

Studies and anecdotal evidence have shown that 30 N/cm is the value considered to be sufficient for primary stability. Below this level, an implant has always been considered highly susceptible to failure by lack of stability. There are two types of torque that we see when placing an implant — insertion torque and seating torque. When immediately loading dental implants, it is the final insertion torque that is the key to successful treatment. In order to follow an immediate load protocol, a minimum seating torque value of 45 N/cm-50 N/cm is necessary [2].

Webster's Dictionary defines *torque* as a force to rotate an object about an axis. By Newton's Third law of Motion, we can confidently deduce that the torque value a practitioner gets when placing an implant is equal to the resistance to the original rotational force. Basically, you can turn the implant, which is a screw, until it either cannot move axially in a downward direction anymore or the bone around the implant exceeds its deformational limit and can no longer resist the axial rotation (stripping). This deformational limit will vary from a high value in D1 cortical bone to a lower value in D4 medullary bone.

The limitation of just looking at torque is that it does not take into account the stability of the implant in lateral directions (**Figure 1**). It is this lateral stability, or

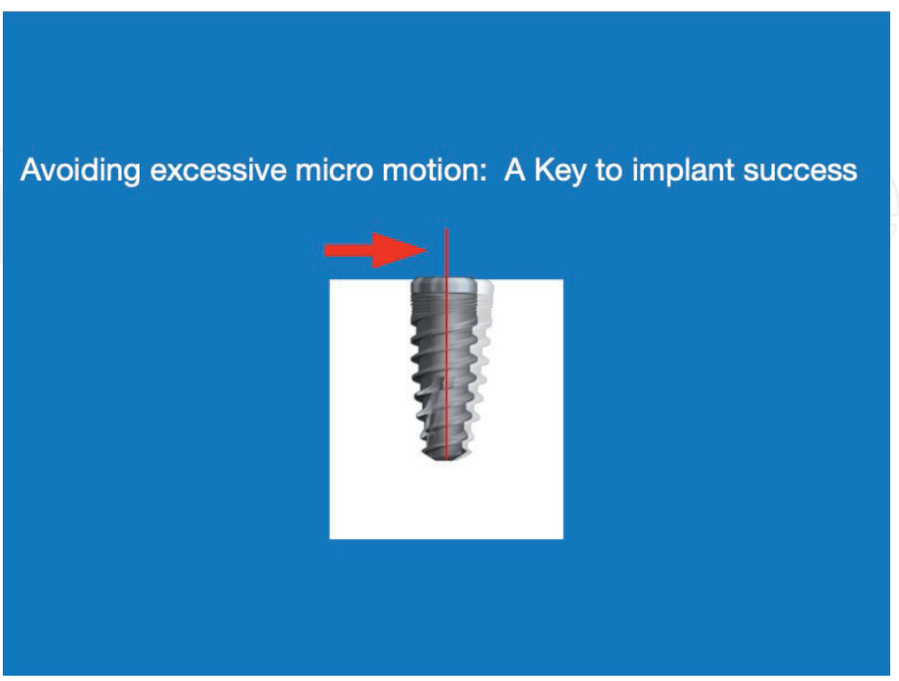


Figure 1.
100–150 microns of lateral movement will result in soft tissue encapsulation.

resistance to sliding motion between the implant and the osteotomy, that is crucial to success. Therefore, it is possible to have a low torque value with high lateral stability or the opposite situation where you have high rotational stability (torque) and low lateral stability (ISQ) [3].

4. Reverse torque

This type of evaluation of implant stability carries with it a potentially high possibility of a negative outcome. This test uses a torque wrench set at 20-30 N/cm and the implant is then subjected to a rotational force in the counter-clockwise direction. Though, in most integrated situations this should not be an issue, it is possible to break integration in softer bone types such as D4 bone or if done too early in the healing process in other bone types.

5. Periotest

The Periotest device was originally designed to measure the mobility of teeth by using a pneumatic plunger that would read the deflection of the tooth in the natural peridontium. In 1990, Olive et al. used it to test the stability of dental implants [4]. The values reported by the device range from −8 to +50. **Figure 2** shows the values for interpreting implant stability, and **Figure 3** shows the values associate with natural teeth.

Unfortunately, because the Periotest value is strongly related to the excitation direction and position, the reading from the method does not always correspond precisely to a biomechanical parameter [5]. Another possible cause for a false reading is that the clinicians hand, or ability to not move that hand becomes part of the equation. If some of the percussive force is either resisted too much or absorbed too much, the readings will not be true.

Periotest Value Range	Interpretation
-8 to 0	Good osseointegration; the implant is well integrated and pressure can be applied to it
+1 to +9	A clinical examination is required: the application of pressure on the implant is generally not (yet) possible
+10 to +50	Osseointegration is insufficient and no pressure may be allowed to act on the implant

Figure 2.
Periotest value range.

Clinical degree of loosening	Periotest value
0	-08 to +09
I	+10 to +19
II	+20 to +29
III	+30 to +50

Figure 3.
Periodontal mobility classification vs. Periotest values.

6. Time

Historically the integration of implants was based on the data collected on natural bone healing and the integration times of the early non-coated implants developed by Branemark. A healing phase of 4–6 months was not uncommon and in many practices all implants were placed in this specified healing time frame.

The issue with this is that every individual is unique. Though the majority of individuals fall into the averages for the time required for integration, the advent of new technology and the differences in individual biology can greatly alter the time to restoration.

7. Bone healing

Osseointegration follows a common, biologically determined program that is subdivided into 3 stages:

- Incorporation by woven bone formation;
- Adaptation of bone mass to load (lamellar and parallel-fibered bone deposition)
- Adaptation of bone structure to load (bone remodeling).

Osseointegration is also a measure of implant stability, which can occur at 2 different stages: primary and secondary. Primary stability of an implant mainly comes from mechanical engagement with compact bone. Secondary stability, on other hand, offer biological stability through bone regeneration and remodeling. The former is a requirement for secondary stability. The latter, however, dictates the time of functional loading [6].

In order to understand RFA and what it is measuring, one must understand implant stability and the factors that influence it. At the time of implant placement, 100% of the stability comes from the relationship between the geometry of the implant and the peri-implant bone. The implants macro geometry; such as thread patter and size, shape of the body of the implant (tapered or parallel walled) and the roughness of the surface coating, or micro-geometry all effect the mechanical locking ability in bone. On the other side of this equation there is the bone itself. The initial stability, or mechanical retention is directly affected by the quality of the bone that the implant is inserted into, with bone types ranging from D1 to D4.

D1 bone has very little medullary bone and therefore mainly consists of cortical bone which is very dense and highly mineralized. As we move down the progression scale towards poorer bone quality, we see an increase in medullary or cancellous bone, with its large non-mineralized spaces between the trabeculae. On the opposite side of the spectrum there is D4 bone which has a very thin mineralized cortical shell that surrounds spongy bone with very little mineralized content and a higher percentage of collagen.

As expected, mechanical stability is usually very high in D1 bone and for the most part very poor in D4 bone with ISQ values supporting this [7].[i]

Biologic stability is attributed to the surface interaction and maturation of bone surrounding the dental implant. The bone, as it is moving through its three stages of change has a direct effect on the stability of the implant. Even after high initial mechanical stability, there is usually a drop off in overall stability during the 3–6 week time period post-placement. This is due to the natural remodeling that occurs as the healing process progresses. There is resorption of bone by osteoclastic activity

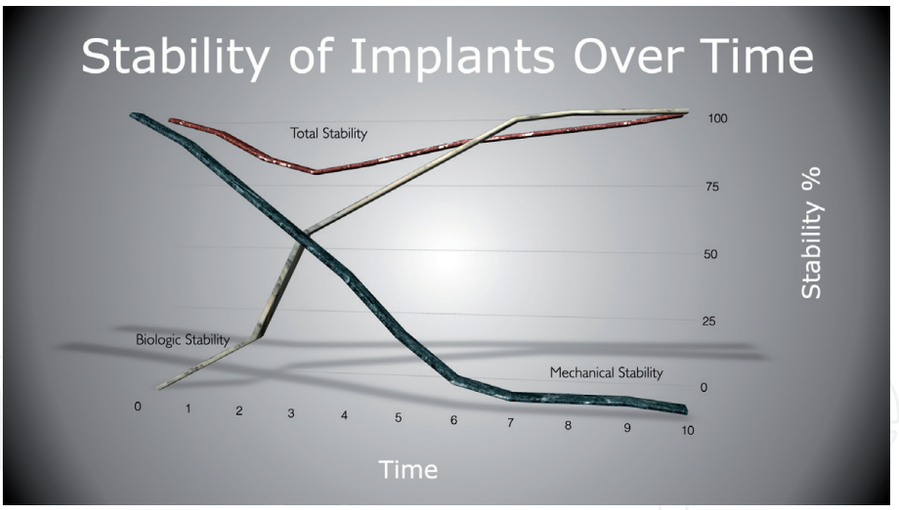


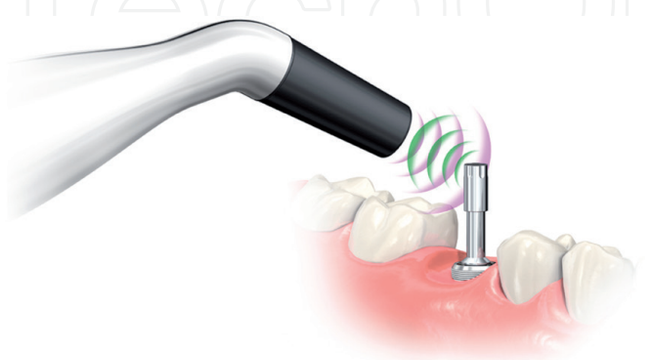
Figure 4.
Comparison of mechanical vs. biologic stability.

followed by the deposition of osteoblasts on the surface of the implant. At this point the un-organized woven bone starts to become organized and the formation of lamellar bone occurs. It is at this point that we see an increase in implant stability afforded by the progression of osseointegration. The next step in the process is maturation and then it is followed by the adaptation of the peri-implant bone to the forces of mastication and load. This cross-over can be seen in the diagram above (**Figure 4**).

8. RFA

Resonance Frequency Analysis for implant stability was first proposed by Merideth in his 1996 [8].[i] The first resonance frequency device was developed by Osstell and the device consisted of an L-shaped receiver that mounted on the implant and a transducer that pulsed it with a magnetic frequency.

Resonance Frequency Analysis (RFA) is the measurement of the frequency with which a device vibrates (**Figure 5**). RFA measurements reflect the micromobility of dental implants, which in turn is determined by the bone density at the implant site [9].



Courtesy of Penguin RFA

Figure 5.
How RFA works.

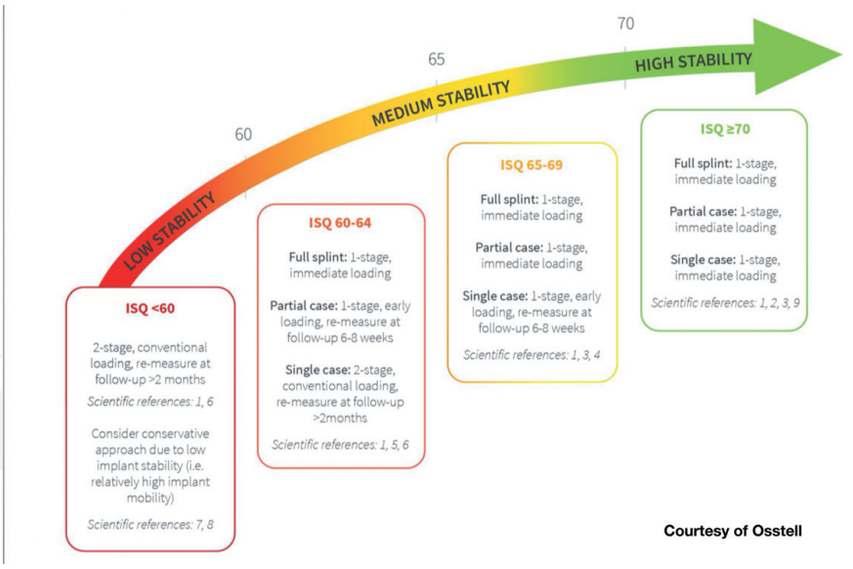


Figure 6.
The ISQ scale provided by Osstell.

A transducer connected to the implant is excited by means of an electric or magnetic impulse (depending on the type of transducer used). Thus, the implant is subjected to slight lateral force that causes lateral displacement due to elastic deformation of the bone. The frequency of the registered oscillation depends on the stiffness of bone-implant attachment: the stiffer the system is, the higher the transducer's oscillation frequency will be. While most tests render subjective results, RFA allows objective, noninvasive assessment of implant stability [10].

Why is the measurement of lateral stability important? If an implant repeatedly moves laterally in the range of 100–150 microns, the body will not form bone at the implant-bone interface, instead, soft tissue will form and the resulting encapsulation of the implant in soft tissue will result in a failure.

ISQ is short for *Implant Stability Quotient.* The ISQ-scale runs from 1 to 100 and corresponds to the resonance frequency in a close to linear way. The scale was determined in 2003, and ISQ 1 correspond approximately to 1,000 Hz and ISQ 100 correspond approximately to 10,000 Hz. The early scientific studies were used to determine how the ISQ scale should relate to Hz and numerous clinical studies after that have put the ISQ-scale in a clinical context, relating to treatment and loading protocols [11].

The developed ISQ scales which are used today give the practitioner a way to quantitatively assess an implants stability. Developed over time by comparing clinical outcomes to ISQ values, thousands of scientific articles have been written that back up the validity of this type of testing device.

The following chart shows the various landmark values for ISQ and what they mean clinically (**Figure 6**). These values are pivotal to successful treatment and not only help direct the initial treatment with regard to deciding on a one stage vs. two stage surgery, but also the progression of healing and the correct time period in which to restore.

9. RFA devices

The two major players in the arena of RFA are Osstell and Penguin. They both work in similar fashion, but the systems differ a bit in their armamentarium.

Figure 7.
The evolution of the Osstell device.

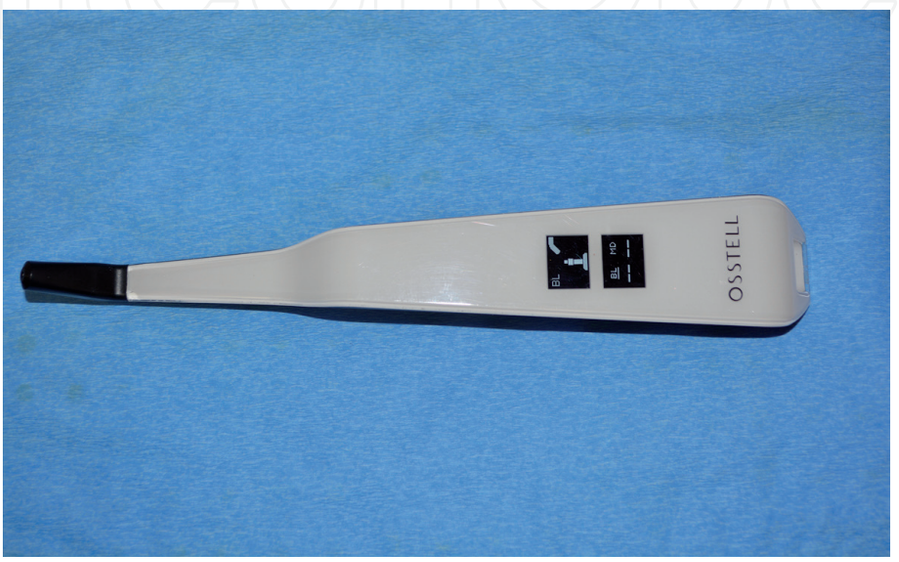


Figure 8.
The Osstell Beacon.

10. Osstell

Starting in 2001, the first commercially available RFA device was released for clinical use. Over the years the Osstell family of devices has evolved to become more accurate and ultimately smaller (**Figure 7**). The features available to the clinician are broad with the large library of clinically backed literature available at www.osstell.com, and clinical tracking ability through www.osstellconnect.com.

The newest Osstell device is the Beacon which is smaller than previous iterations and lights up with either red, yellow or green to correspond to the values on the ISQ scale (**Figure 8**).

11. Penguin RFA

Emerging onto the scene in 2015, The Penguin RFA device uses similar technology as the Osstell and when it was introduced, was the first device to decrease the overall size of an RFA device to the size of a portable curing light (**Figure 9**).

12. Comparing the two devices

Both devices utilize a peg that is screwed into the abutment connection of the implant. These pegs are not only platform diameter specific, but also implant/

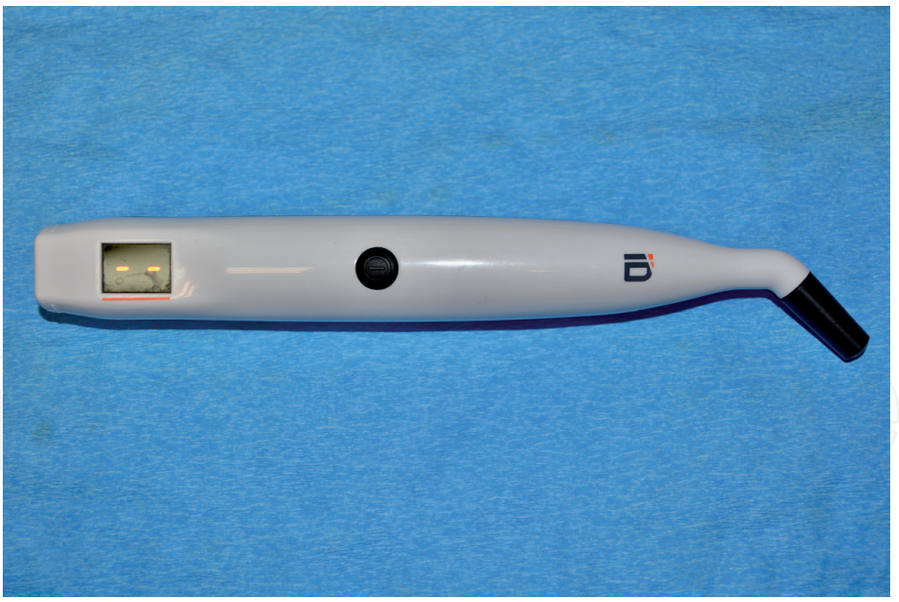


Figure 9.
The penguin RFA device.

abutment interface type specific. Therefore, you must have different pegs for different implants.

The Osstell unit utilizes single use Smartpegs which are made of aluminum (**Figure 10**). The use of aluminum was chosen in order to prevent accidental cross-threading of the peg from damaging the threads inside the implant. On the other hand, the penguin RFA unit uses Multipegs made of titanium (**Figure 11**). These pegs are multi-use and can be sterilized and re-used approximately 20 times before replacing. The reason they must be replaced is that after repeated thermal cycling in an autoclave, the ductility of the titanium peg can

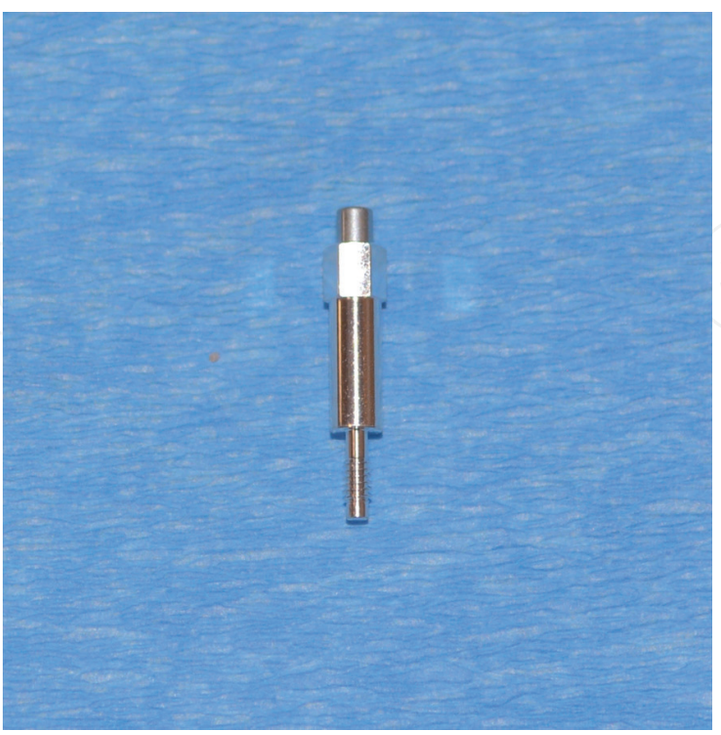


Figure 10.
Osstell Smartpeg.

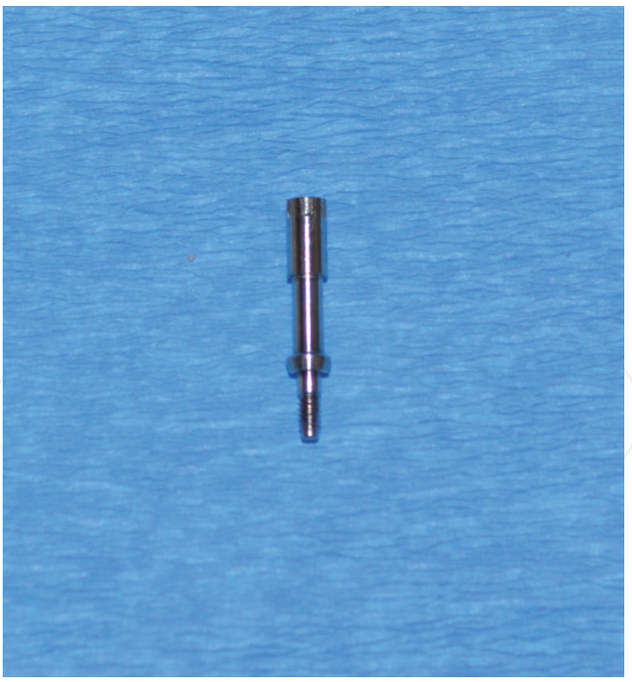


Figure 11.
Penguin multipeg.

Figure 12.
Penguin (L) and Osstell (R) calibration pegs.

change and I have seen the small magnet become corroded, both of which can result in inaccurate readings.

Both the Osstell and Penguin RFA units have calibration pegs (**Figure 12**) which are available. The Osstell peg is set to give an ISQ of 55 and the Penguin will give a reading of 45-55. Since the Osstell pegs are single use and calibrated at the factory, further calibration of the unit is not necessary according to the manufacturer. The Penguin on the other hand, with its multi-use pegs may benefit from the ability to check calibration as they are being re-used.

13. Discussion

The success of dental implants is affected by various factors according to the oral and general health of the patient, and it has been reported that the ISQ values vary in a range between 58 and 84, with a mean of 68 after 8–12 months [12].

When trying to provide not only predictability, but also expedient treatment, the use of an RFA device is invaluable. These devices provide a much better indicator of the level of osseointegration than all the other methods available. They are easy to use and only take a few moments to get ISQ values. Measurements are taken in the BL direction and in the MD direction while directing the transducer at an angle of 45 degrees to the peg (**Figure 13**).

Intra-operatively it is a simple procedure and provides the data you need to make intelligent clinical decisions (**Figure 14**). At placement an ISQ value of 55 is equivalent to the use of torque value where a measurement of 30 would indicate sufficient primary stability in order to safely place a healing abutment for a 1 stage or early loading protocol. Any lower ISQ would indicate to the clinician that a two-stage protocol by burying the implant would be prudent. If a stability of 70 or above then immediately loading a single implant could be done safely.

In my clinical protocol, I take measurements at placement and then again at 8 weeks. At that time, I can make a determination of where the implant is in the healing spectrum. If the ISQ number has reached a minimum of 70, then I will

Figure 13.
Angle to test stability showing "green" ISQ value.

Figure 14.
Osstell IDX being used clinically.

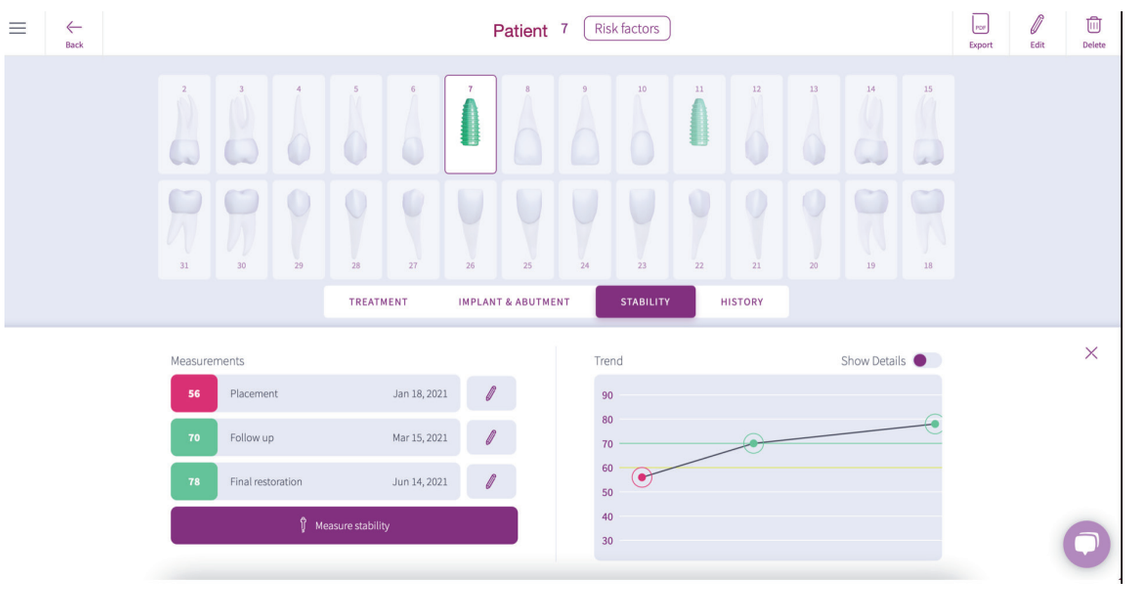


Figure 15.
Screenshot of clinical interface on Osstell connect.

proceed to the restorative phase with confidence. If it is somewhere between my initial measurement and 70, then I will wait another month and re-check.

Clinically this is not only tracked in my digital notes, but also on the Osstellconnect site (**Figure 15**). Conversely, if the ISQ number has dropped significantly below my initial reading at placement, it indicates a failing or failed implant and the decision to remove it is discussed with the patient. Even though this is an event that no one wants, at least it is identified early enough that a new implant can be placed and the patient only loses two months in the overall treatment time.

When compared with the use of RFA, Osstell™ system proved to be more reliable compared to Periotest® system in measuring dental implant stability in hard and in soft interfaces [13]. In 2020 when comparing the Osstell to the Penguin, Bural et al. saw no statistical difference in their readings [14].

Today, RFA is being used in clinical research to quantify differences in implant designs and surface technology. It was used to determine the difference in stability and bone loss associated with implants with differing crestal macro structures and thread designs [15].

Also, RFA was able to show that rehabilitations with splinted crowns combining 4- and 10-mm implants demonstrated a favorable 1-year performance in a shortened maxillary dental arch [16].

These instruments are allowing clinical researchers to dissect the parameters and minutia that contribute to overall implant success. For example, the use of RFA has shown that there is no differences in stability of implant or failure rate between men and women [17].

Yet, in Peter Andersson's 2019 publication, he did find that women had lower ISQ values than men, which he and his colleagues attributed to the incidence of osteoporosis in female patients. These diametrically opposed outcomes will spur further studies into the differences in success between the sexes and what critical factors may be responsible.

He Also found that there was a significantly higher risk for failure for implants with an ISQ value below 70 and 75 than for implants with higher stability at placement. Moreover, the risk for failure increased further if the ISQ value was still below 70 and 75 after 3–4 months of healing [18].

As you can imagine, research like this, is and will allow, us to treat more patients effectively and predictably.

The use of RFA is helping to develop better techniques for regeneration and help quantify the role that biologics like platelet-rich fibrin may have in enhancing healing and contributing to better implant stability [19].

Todays world of implantology if filled with wonderful technology to help practitioners and patients alike. CBCT technology, digital CAD/CAM and 3D printing all are used to provide the very best in patient care. RFA allows for a better understanding of primary stability, the healing process of osseointegration and takes the guesswork out of know when to restore.

Author details

Charles D. Schlesinger
FICOI, Albuquerque, New Mexico, USA

*Address all correspondence to: cdschlesinger@gmail.com

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